moffatt & nichol

RISK AND VULNERABILITY ASSESSMENT

Town of Leland, NC

Town of Leland

April 1, 2022

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EXECUTIVE SUMMARY

This assessment examines the risks, vulnerabilities, and degree of exposure to natural hazards of the Town of Leland and its population, built environment, and natural infrastructure now and into the future. The Town of Leland has experienced rapid population growth consistently over the past two decades, and thus is planning for the continuation of this trend. Coinciding with plans for rapid development and population increases, plans for future land use that incorporate goals of protecting the natural environment are imperative for smart growth.

Direct impacts to critical facilities, natural infrastructure, property, and population are also examined in this assessment. Responses from a community-wide public survey aid in providing information on direct impacts experienced by residents. In terms of natural infrastructure, the Town of Leland contains four categories of Areas of Environmental Concerns (AECs), or natural areas of land or water designated as important to protect from uncontrolled or incompatible development. Coastal wetlands, estuarine waters, public trust areas, and coastal shorelines are found within the Town boundaries. Direct impacts from flooding are concentrated around the Town's major water bodies. The majority of properties within the Town are located outside of the 100-year flood zone, however, some properties, including residential, lie within the floodplain and should be key considerations in future land use planning. Similarly, the majority of critical facilities, including medical facilities, institutions, government buildings, and water utility features, are located outside of the 100-year flood zone. However, understanding the placement of these facilities in relation to flood zones, as well as the major evacuation routes in and out of the Town, is crucial in assessing overall risk and vulnerability.

The Town of Leland and its current and future residents are vulnerable to natural hazards including flooding, sea level rise, and storm surge. The methodology used in this assessment helps to provide a better understanding of the degree of vulnerability of certain features as well as the associated risks. Critical facilities, natural infrastructure, property, and the Leland population are in some cases, located in areas within the Town boundary that demonstrate higher risks and vulnerabilities to these natural hazards, providing crucial information for land use and conservation planning. These features were qualitatively assessed using Geospatial Information Systems (GIS) mapping and utilizing data from a variety of sources including local, state, federal, and non-profit agencies.

Social vulnerability was assessed using the Center for Disease Control (CDC) guidelines. According to the results, the census block at the north of the Town showed the highest vulnerability followed by the growing residential area at the west end of the Town.

Loss estimates obtained using GIS were used to quantitatively assess vulnerability. Loss estimates included numbers of buildings, and critical facilities located in the identified hazard areas, an estimate of the potential losses to vulnerable structures. Additionally, an overall vulnerability score was assigned to each critical asset using the responses from Community Action Team (CAT) members. The governmental buildings in the Town were ranked to have higher vulnerability according to the survey results.

1. INTRODUCTION AND AREA OVERVIEW

1.1. Study Area and History

The Town of Leland is located in southeastern North Carolina in Brunswick County and is approximately 21.28 square miles in size. The municipal boundaries of the Town are adjacent to the Brunswick River and Cape Fear River to the east, with the Cape Fear River connecting directly to the Atlantic Ocean approximately 30 miles downstream.

Due to the proximity of the rivers and the fertile soil, the area that is now Leland historically was home to rice growing plantations. Eagles Island, located between these rivers directly east of Leland, was used for rice cultivation for many years and to this day, has irrigation canals running through the island.

Also because of its proximity to the Brunswick River, the Town of Leland originally served as an early transportation center in the late 19th and early 20th century. Both the Brunswick River and Cape Fear River transported residents and visitors to and from Leland by ferries. However, the wetness of the soil and the swamps made transportation by land difficult. Maintaining connectivity between Leland and its surrounding cities required major roads to be hardened in order to withstand the area's conditions. Today, Leland is home to residents who commute to and from the surrounding larger municipalities and its growth can be partly attributed to its connectivity and proximity to these areas.

Over the past two decades, Leland has experienced rapid growth and expansion due to expansion of water and sewer services along with an influx of migration (particularly retirement age) moving into the region. This can be attributed to the community's lifestyle choices, weather, amenities, and cost of living. Because of this rapid growth, high value continues to be placed on access to open space and pedestrian and bike-oriented amenities that allow residents to meet daily needs within a close proximity to their homes, while providing additional recreation opportunities.

1.2. Existing Land Use

Currently, Rural Residential and Low-density Single Family land use are the predominant land uses in the Town of Leland. Land classified as Rural Residential by Brunswick County tax records accounts for 9,293 acres and Low-density Single Family land parcels account for 3,534 acres. This makes up approximately 65% of the entire land area within Leland's municipal boundaries, which coincides with the development trends of the past 20 years and projected growth.

Reflective of the high value of open space and recreation opportunities, the amenity-oriented trend has come into play with land use planning in the Town of Leland and resulted in 613 acres of land classified as Natural Open Space and 23 acres of land classified as Conservation. Additionally, commercial land has seen an increase in value over the past 20 years and thus, Leland currently has 2,695 acres of commercially zoned land parcels.

1.3. Future Land Use Planning

The Town of Leland is set to expand by 2045 into a larger municipal area. The Leland 2045 comprehensive land use plan provided a growth framework that could expand Leland's land area from 19,749 acres to 94,536 acres. Into the future, it is expected that the amenity-oriented trend will continue to accelerate in an increase in Conservation zoned land areas and Natural Open

Space zoned land areas. The planning area analyzed in the Leland 2045 comprehensive land use plan 2,704 existing acres of Conservation land and 1,488 acres of Natural Open Space land. This 2045 planning area also exhibits a relatively high amount of Commercially zoned land, with 3,628 existing acres currently, and the pattern of increasing commercial development is expected to continue. Residential development is trending towards higher densities and displaying a trend known as the “missing middle”, which is accounted for in the Leland 2045 comprehensive land use plan in an increase in middle-density residential development.

1.4. History of Disaster Declarations

Brunswick County has a total of 28 presidentially declared disasters in the Federal Emergency Management Agency’s (FEMA) official listing of disaster declarations. Out of these declared disasters, two were categorized as severe storms and 23 were categorized as hurricanes, with the others being biological or other hazards. Both severe storms on record brought flooding to the area—Tropical Storm Hanna in 2008 and severe storms from remnants of Tropical Storm Nicole in 2010. Out of the 23 hurricanes that occurred, the majority (13) were in the month of September. Four of these hurricanes occurred in October, four occurred in August, one occurred in July, and one in January.

A complete list of these disasters can be found at https://www.fema.gov/disaster/declarations.

Table 1. History of disaster declarations in Brunswick County. (Source: FEMA, 2021)

Year of Declaration Date	Declaration Title	Declaration Type	Disaster Number
1984	Hurricane Diana	Hurricane	724
1989	Hurricane Hugo	Hurricane	844
1996	Hurricane Bertha	Hurricane	1127
1996	Hurricane Fran	Hurricane	1134
1998	Hurricane Bonnie	Hurricane	1240
1999	Hurricane Dennis	Hurricane	3141
1999	Hurricane Floyd Emergency Declarations	Hurricane	3146
1999	Hurricane Floyd Major Disaster Declarations	Hurricane	1292
2003	Hurricane Isabel	Hurricane	1490
2005	Hurricane Katrina Evacuation	Hurricane	3222
2005	Hurricane Ophelia	Hurricane	1608, 3254
2008	Tropical Storm Hanna	Severe Storm	1801
2010	Hurricane Earl	Hurricane	3314
2010	Severe Storms, Flooding, and Straight-Line Winds from Tropical Storm Nicole	Severe Storm	1942
2011	Hurricane Irene	Hurricane	3327, 4019
2016	Hurricane Matthew	Hurricane	3380, 4285
2018	Hurricane Florence	Hurricane	3401, 4393
2019	Hurricane Dorian	Hurricane	3423, 4465
2019	Tropical Storm Michael	Hurricane	4412
2020	Hurricane Isaias	Hurricane	3534

2. RISK ASSESSMENT METHODOLOGY AND ASSUMPTIONS

2.1. Qualitative Methodology

The data used in this assessment was obtained from a variety of sources, including federal, state, and local agencies, as well as nonprofit organizations. These data sources, along with their corresponding maps and feature layers are displayed in **Table 2**. Some data was not explicitly given and had to be calculated. For instance, the data obtained from the US Census provided the number of individuals in the total population for each block group as well as the number of individuals in each age range in the Census data. In the social vulnerability maps displaying vulnerable age groups (65 years and older, under five years, and under 18 years), the percent of population under/over each age range was calculated using ArcMap field calculator.

Additionally, some feature layers were created manually. For instance, some critical facilities, such as government buildings, were created as new points, due to the fact that Brunswick County GIS Data did not have all of the newly developed facilities in its data collection. For these facilities, building addresses were provided by Town staff and latitude and longitude coordinates were identified based on the address.

Some feature layer data was modified for the purpose of readability and simplification. For example, the SLOSH (Sea, Lake, and Overland Surge from Hurricanes) data obtained from the National Oceanic and Atmospheric Administration (NOAA) for use in the Storm Surge map displayed dozens of colors and various ranges for each hurricane category. New fields were added to the attribute table in ArcMap to collate any and all shapefiles within the range for each category and color coding was applied to the entire field, so that each hurricane category would be represented by a single color for easy readability. To create the Municipal Zoning Parcels and Flood Zones map, a similar methodology to the Storm Surge Map was used.

Table 2. List of Maps, feature layers displayed in each map, and data sources for each feature layer data set used for all GIS map products included in Risk and Vulnerability Assessment

Map	Data/Feature Layer	Data Source
Natural Infrastructure	• Streams • Wetlands	• https://data-brunsco.opendata.arcgis.com/ • https://deq.nc.gov/about/divisions/coastal-management/coastal-management-data/setback-factor-maps-1998-shoreline/coastal-wetlands-spatial-data#Wetlands
Critical Features And Flood Zones	• Fire Stations (proposed and existing) • Medical Facilities • Senior Living Facilities • Day Care Centers • Schools • Government Buildings • Lift Stations • Culverts • Flood Hazard (NCFRIS)	• https://data-brunsco.opendata.arcgis.com/ and Town of Leland • Same as above • Same as above • Same as above • Same as above • Same as above • Town of Leland, and H2GO • Same as above • https://fris.nc.gov/fris/Download.aspx?FIPS=019&ST=NC&user=General%20Public
Roadways and Evacuation Routes	• Major Road • Other Major Road • NC Highways • Town Owned Streets • Flood Hazard (NCFRIS)	• ESRI, Tele Atlas North America • https://data-brunsco.opendata.arcgis.com/ • https://fris.nc.gov/fris/Download.aspx?FIPS=019&ST=NC&user=General%20Public
Municipal Zoning Parcels and Flood Zones	• Municipal Parcels • Flood Hazard (NCFRIS)	• https://data-brunsco.opendata.arcgis.com/ • https://fris.nc.gov/fris/Download.aspx?FIPS=019&ST=NC&user=General%20Public
Storm Surge Inundation	• Storm Surge Inundation (SLOSH model), hurricane categories 1-5	• National Storm Surge Hazard Maps - Version 2 (noaa.gov)
Sea Level Rise Inundation	• Sea Level Rise (1-10 ft)	• https://coast.noaa.gov/slrdata/
Previous Hurricane Flood Inundation	• Hurricane Matthew and Hurricane Florence areas of inundation	• The Nature Conservancy, 2020 (https://knb.ecoinformatics.org/view/doi:10.5063/F1JM280P)
FEMA Flood Zones	• 100-Year Flood Zone • 500-Year Flood Zone	• North Carolina Flood Risk Information System (NC FRIS)

Quantitative Methodology

2.1.1. Social Vulnerability Methodology

Social vulnerability refers to the inability of people, organizations, and societies to anticipate, cope with, resist, and recover from the impact of external stresses. Understanding social vulnerability can help identify communities in greatest need of resources.

To determine social vulnerability within the Town, the Social Vulnerability Index (SVI) method adopted by CDC was used (Flanagan et al., 2011). CDC's SVI makes use of U.S. Census data to determine social vulnerability. The SVI ranks each census area on 15 socio-economic factors, and groups them into four themes (socioeconomic status, household composition, minority status/language, and housing/transportation), as listed in **Table 3**. Each census area receives a separate ranking for each of the four themes, as well as an overall ranking.

Table 3. CDC social vulnerabilty index themes and variables (adapted from CDC,2015)

OVERALL VULNERABILITY	**Socioeconomic Status**	Below Poverty
		Income per Capita
		Unemployment
		High School Education
	Household Composition	Aged 65 and Older
		Aged 17 and Younger
		Older than Age 5 with Disability
		Single-Parent Household
	Minority Status & Language	Minority
		Speaks English "Less Than Well"
	Housing & Transportation	Multi-Unit Structures
		Mobile Homes
		Crowding
		No Vehicle
		Group Quarters

To develop the SVI, each of the 15 census variables, except income per capita, were ranked from highest to lowest across census blocks in the Town of Leland. Since a higher income indicates lesser vulnerability, income per capita was ranked from lowest to highest. A percentile rank was then determined for each census block over each of these variables. Percentile ranking values ranged from 0 to 1, with higher values indicating greater vulnerability. For each census block, its percentile rank among all blocks were determined for 1) the 15 individual variables, 2) the four themes, and 3) its overall position. The rank of the census blocks for each theme was determined by adding the percentile ranks of the variables comprising that theme. Finally, an overall vulnerability ranking was calculated as the sum of the theme percentile rankings.

2.1.2. Loss Estimates

Loss estimates were determined using a GIS-based analysis. The aim of this assessment was to determine economic losses at buildings due to possible hazard events. To identify vulnerable structures to a specific hazard, the best available spatial hazard risk data and building footprint data were overlaid and compared. Finally, Depth-Damage Functions adopted by USACE in the North Atlantic Coast Comprehensive Study (USACE, 2015) were used to calculate the potential economic damages inflicted upon each structure in the hazard zone based upon inundation depth, first floor elevation, building type, and the value of the building and its contents.

3. HAZARD IDENTIFICATION

3.1. Flooding

Flooding is defined as the accumulation of water within a water body which results in the overflow of excess water onto adjacent lands, usually floodplains. A floodplain, by definition, is the land that adjoins the channel of a water body such as a river, stream, ocean, or lake, that is susceptible to flooding. FEMA identifies specific flood zones based on the likelihood of the area flooding. The 100-Year Flood Zone represents areas that have a one percent chance of being inundated by flood waters in a given year. Similarly, areas depicted as being within the 500-Year Flood Zone have a 0.2 percent annual chance of being inundated by flood waters in a given year. The areas outside of these zones are determined to be of minimal risk. The 100-Year and 500-Year Flood Zones within the Town of Leland are displayed in **Figure 1** below.

Flooding is a generalized term that can be categorized into many types: riverine flooding, coastal flooding, flooding from storm or heavy precipitation events, or shallow flooding. Shallow flooding refers to flooding from ponding or urban drainage. Because of its proximity to the coast and riverine water bodies, the Town of Leland is exposed to all of the above-mentioned flood hazards. Flooding from major storm events has brought severe impacts to the Town in previous years and has become a major hazard concern, as illustrated in **Figure 2**.

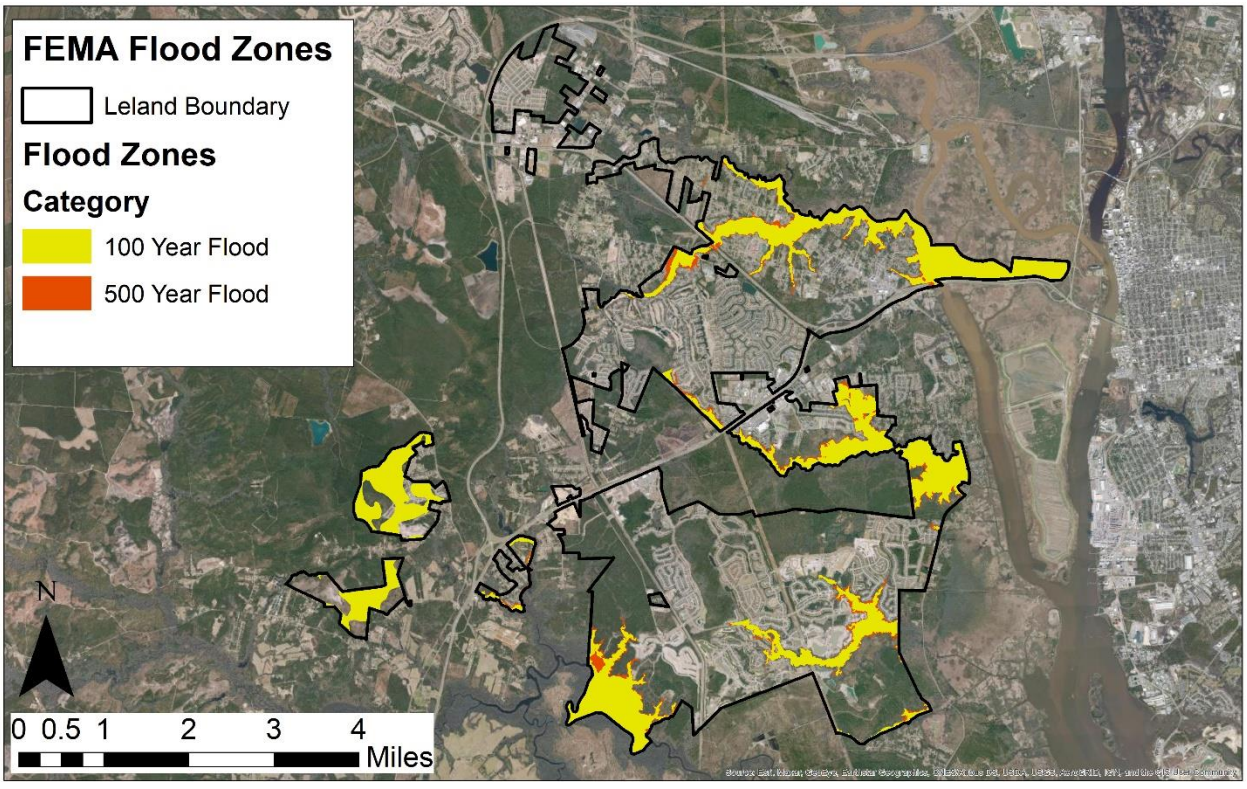

Figure 1. Map displaying the FEMA 100-Year Flood Zones and 500- Year Flood Zones within Town of Leland's boundaries.

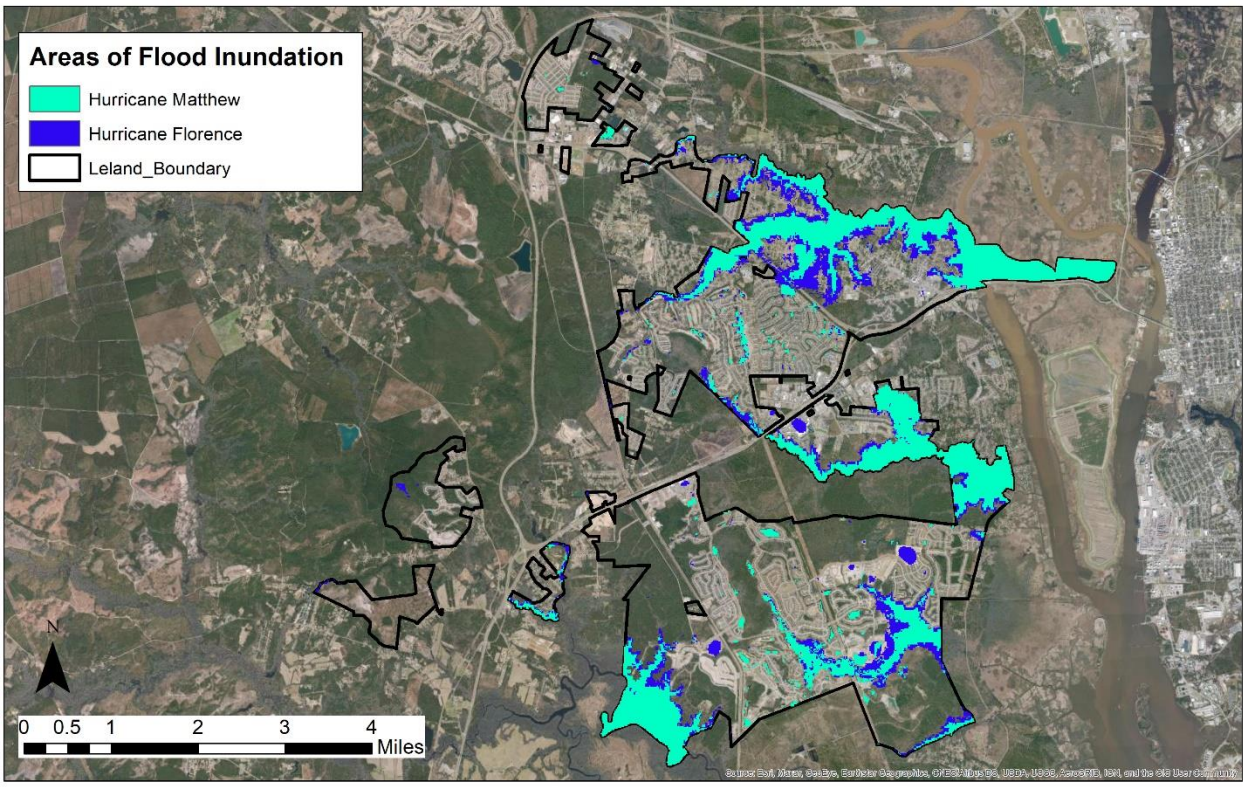

Figure 2. Map displaying areas of flood inundation within the Town of Leland's boundaries from Hurricanes Matthew and Florence. (Source: The Nature Conservancy)

3.2. Storm Surge

Storm surge is defined as a large expanse of water, often 50 or more miles wide, and rising several feet during a hurricane, up to more than 30 feet in a Category 5 storm (national average). The height of a storm surge and its associated waves can be dependent upon many factors such as the shape of the offshore continental shelf and the depth of the ocean bottom offshore. For example, lower surges tend to result from a narrower continental shelf but can bring higher and more powerful storm waves. Storm surge arrives ahead of a storm or hurricane's actual landfall and will arrive sooner the more powerful the storm event is offshore. Water rise caused by storm surge can be very rapid and therefore pose a serious threat to those properties or individuals located in flood-prone areas. The area forecasted to be inundated by flood waters from Storm Surge within the Town of Leland is depicted in **Figure 3**, illustrated by each individual hurricane category.

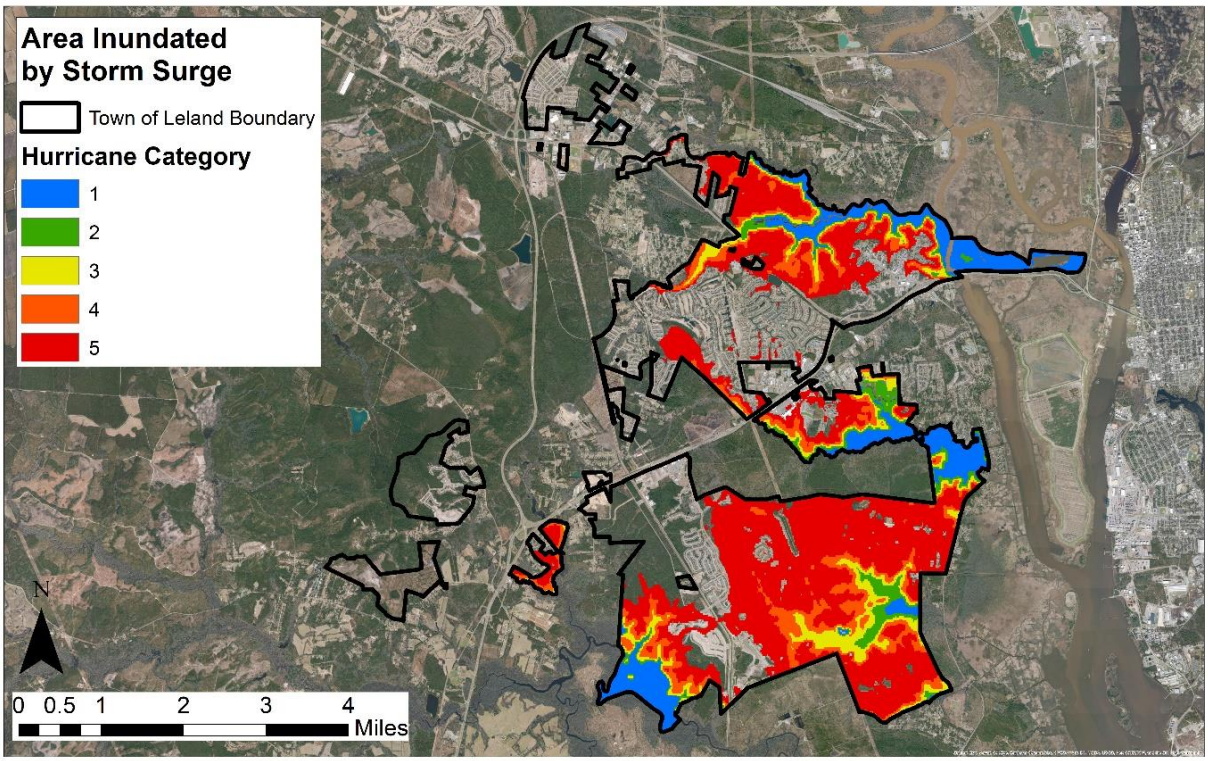

Figure 3. Map displaying areas exposed to storm surge within the Town of Leland's boundaries from storm surge by hurricane category. (Source: NOAA SLOSH data)

3.3. Sea Level Rise

Sea level rise can be defined as the rising of the seas above their current levels. This can have potentially major and catastrophic impacts by not only causing inundation of areas not previously inundated with water but by exacerbating the other above-mentioned hazards. Sea level rise is a threat associated with climate change and is becoming a larger threat to communities along the coast each year. It is caused primarily by the thermal expansion of the oceans and the loss of land-based ice. search included in NOAA's Sea Level Rise Report indicates that the rate of sea level rise globally has been accelerating steadily over the past century, however the rate of acceleration is becoming more and more rapid and will have increasingly more devastating effects on coastal communities over time.

In North Carolina, the rate of local sea level rise varies depending on effects of water movement in the Gulf Stream as well as land subsidence. Studies conducted by the North Carolina Department of Environmental Quality (NCDEQ) show that southeastern North Carolina, including Brunswick County, is experiencing less land subsidence than the more northern portion of the coast, north of Cape Lookout. Therefore, southeastern North Carolina coastal counties are experiencing lower measured rates of sea level rise than those counties further north. According to tide gauge projections measured by NOAA and reported by NCDEQ; the Eagles Island area is seeing an average rise of 2.4 inches in sea level every 30 years. In comparison, parts of the northern coastline of North Carolina see more than twice this rate of sea level rise at 5.4 inches every 30 years. However, sea level rise by itself or in combination with other hazards such as storm surge or heavy precipitation events, is a serious concern for southeastern North Carolina.

As mentioned above, NOAA tide gauge data taken from Eagles Island just east of Leland exhibits a trend of 2.4 inches in sea level rise every 30 years. When estimating sea level trends, a minimum of 30 years of data are used in order to account for long-term sea level variations and to reduce errors in computing sea level trends based on tide gauge data that is taken monthly. In a 100-year planning period, the continuance of this sea level rise trend exhibited at and around the Eagles Island vicinity would result in a relative mean sea level increase of approximately 8 inches. Areas that are anticipated to be inundated by sea level rise within the Town of Leland according to NOAA sea level rise modelling data are displayed below in **Figure 4**, illustrated by every one-foot increase in sea level. NOAA sea level rise flood hazard modelling data uses a modified bathtub approach to account for local and regional tidal variability as well as hydrological connectivity, mapping sea level rise on top of existing mean higher high water (MHHW) conditions.

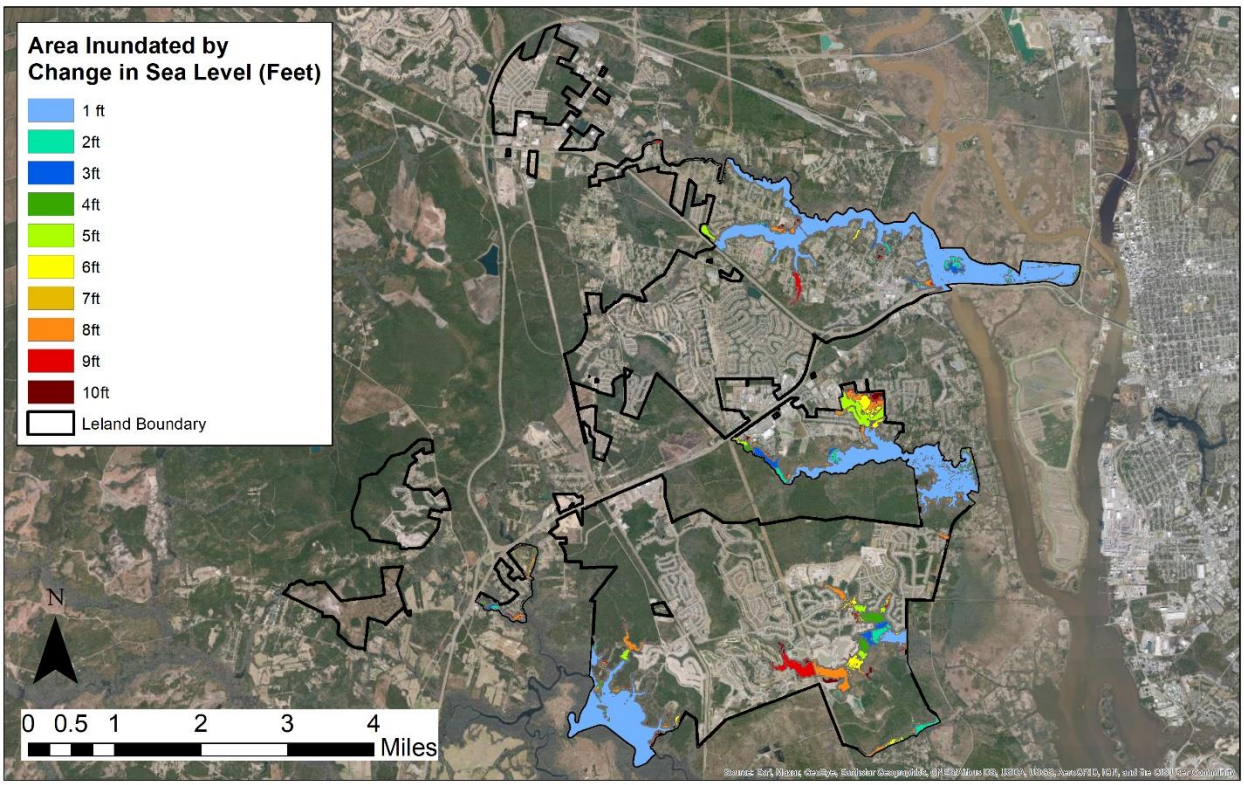

Figure 4. Map displaying areas inundated within the Town of Leland's boundaries from changes in sea level rise by one-foot increments. (Source: NOAA, 2017)

4. COMMUNITY ASSET INVENTORY

4.1. Population

Leland currently has an estimated 8,877 housing units and expects to need a total of 21,689 housing units by 2045 in order to accommodate anticipated population growth. The most recent data from 2020 Census records concludes that the Town of Leland saw a population increase of 70% since 2010, increasing from 13,527 to 23,049 in 2020. The average household size in the town is 2.43 persons as of 2020 data listed in the Town's Leland 2045 comprehensive land use plan, which is slightly higher than that of Brunswick County (at 2.34 persons per household) and slightly lower than North Carolina (2.52 persons per household). The average age of Leland residents is 46.2, which is higher than North Carolina's average of 38.7. The relatively high average age is in part due to the steadily increasing number of residents over the age of 65, which has seen an increase of over 25% over recent years. Additionally, Leland has a higher proportion of residents under 5 years of age (6.5%) than the state (5.8%) and the county (3.7%). The proportion of residents under the age of 18 in Leland (19.5%) is lower than the state (21.9%) but higher than the county (14.7%). The majority of Leland's population identifies as White alone (83.8%), with 8.8% identifying as Black, 4.5% as Hispanic, 1.8% as Asian, and 0.9% as American Indian. Because of the limited number of hotel rooms and Airbnbs or rental units, the seasonal population is not substantially different from the yearly population.

4.1.1. Direct Impacts

Based upon a public survey that was distributed to residents of the Town of Leland, stakeholders, and the surrounding community (from July 16th, 2021 to September 11th, 2021) as part of this assessment, approximately 87% indicated they reside within Leland city limits, and approximately 50% own residential property in Leland. Just over half (51%) of respondents indicated that they have been directly impacted by a disaster caused by a natural hazard such as flooding, storm surge, or erosion. **Table 4** illustrates the types of natural hazards experienced by those individuals that answered "yes" to being directly impacted by such disasters. Those who answered "other" gave responses that included hazards such as fallen trees, hail damage, and wind damage.

Table 4. Natural hazards that residents of the Town of Leland and its vicinity stated to have directly impacted them previously.

Natural Hazard	Percent of Respondents
Flooding caused by storm surge and/or rainfall from tropical systems	60.00%
Flooding caused by thunderstorms and intense rainfall	58.67%
Stormwater	44.00%
Flooding caused by tidal surge (king tides and/or higher than normal tides)	6.67%
Riverine flooding	5.33%
Riverine erosion	0.00%
Sea level rise	0.00%
Other	18.67%

4.1.2. Future Vulnerability and Land Use

According to Town records, Leland has an insufficient supply of affordable housing to accompany the increased demand that comes with the growth the municipality has been experiencing and is expected to experience going forward. The demand for affordable housing will only be exacerbated as areas of lesser exposure to natural hazards continue to be developed and those areas of higher exposure and vulnerability are left. To address natural hazard concerns, however, the Town has policies and ordinances in place to address development in flood-prone areas. For example, Snee Farm and Highland Hills have undergone drainage projects as residential developments have seen frequent flooding; and the most updated version (2021) of the Town's stormwater ordinance includes design controls for development sites to minimize direct impacts of developments to hydrology of the surrounding communities.

4.2. Natural Infrastructure

The Town of Leland contains four categories of CAMA Areas of Environmental Concerns (AECs), or natural areas of land or water designated as important to protect from uncontrolled or incompatible development. Coastal wetlands, estuarine waters, public trust areas, and coastal shorelines are found within the Town boundaries. Coastal wetlands are defined as any marsh subject to tidal influence, regular or occasional tidal flooding, not including hurricane or tropical storm tides. Estuarine waters include all the waters of the bays, sounds, rivers, and tributaries seaward of the dividing line between coastal and fishing waters. Public Trust areas are defined in the Coastal Areas Management Act as those waters of the Atlantic Ocean and the lands lying under from the mean high-water mark to the three-mile seaward limit, all natural bodies of water subject to tides and lands laying under, and all navigable natural bodies of water and lands lying under to the normal high-water mark. Coastal Shorelines include estuarine shorelines and public trust shorelines, referring to those areas of non-ocean shorelines extending from the normal high-water level along the estuarine waters for a distance of 75 feet landward, and those areas of non-ocean shoreline immediately contiguous to public trust areas located inland of the dividing line between coastal fishing waters and inland fishing waters and extending 30 feet landward of the normal high-water level.

The Town of Leland's land area contains hydric soil, or soil that is formed under conditions of saturation, flooding, or ponding long enough to develop anaerobic conditions in the upper portion. The soil found in the study area primarily consists of "Group A soils", which have a high infiltration rate, also categorized as a low runoff potential, when thoroughly wet; and have a high rate of water transmission.

The major creeks found within the Town of Leland are Sturgeon Creek, Jackeys Creek, Mallory Creek, and Town Creek. These creeks are all designated by the North Carolina Department of Environmental Quality (NCDEQ) as fresh swamp water. According to their classifications, the best uses for these surface waters are including aquatic life and secondary recreation. The Brunswick River, which runs into the Cape Fear River, is also located within the Town boundaries and is classified as saltwater. This classification indicates this river is suited for aquatic life and secondary recreation. This river is also the only delineated shellfish harvesting water body in the study area and is classified as "prohibited" by the North Carolina Division of Marine Fisheries (NCDCM) for suitability for harvesting for human consumption.

The Town of Leland contains an expanse of non-coastal wetland areas as well as streams abutting from the above-mentioned creeks and rivers. Understanding the geography of this

natural infrastructure is important for understanding the relative ecological importance of these areas and the overall hydrologic functions of the surrounding natural environment. This is displayed in **Figure 5** below.

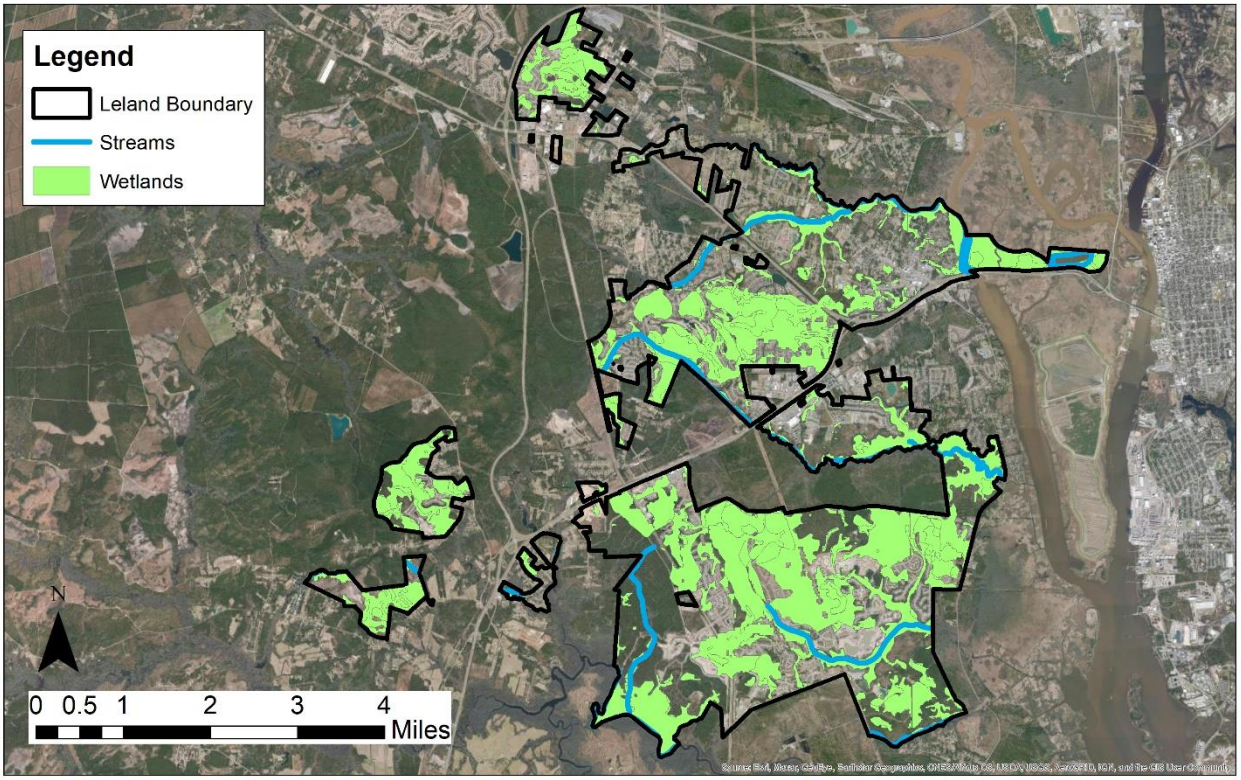

Figure 5. Map displaying the streams and wetlands located within the Town of Leland's boundaries. (Sources: NCDEQ; Brunswick County)

4.2.1. Direct Impacts

According to the Town's records, impacts from flooding are concentrated in the areas surrounding Sturgeon Creek, Jackey's Creek, Mallory Creek, Town Creek, and the Brunswick River. However, the Town does have ordinances and policies in place, such as the Stormwater Ordinance (updated August 2021) and Flood Damage Prevention Ordinance (updated July 2018), that address development in these flood-prone areas. The wetlands within the flood-prone areas around the Brunswick River in particular have been rated as being of exceptional significance in terms of water quality, wildlife habitat, and hydrologic functions by the North Carolina Coastal Region Evaluation of Wetland Significance (NC CREWS). This rating helps to assess the ecological and environmental importance of these areas of natural infrastructure for use in planning.

4.2.2. Future Vulnerability and Land Use

Not only are areas of open space and conservation deemed to be of high value to residents for recreational purposes, but the stream margins and wetland areas within the Town of Leland are of ecological significance to the entire surrounding area. The Town of Leland has made it clear in

planning efforts that protecting environmentally sensitive areas is an essential framework for future land use planning in Leland and in the 2045 planning area.

4.3. Property

As stated previously, within Leland's municipal boundaries, there are currently an estimated 8,877 homes. Furthermore, the 2045 Comprehensive Future Land Use Plan exhibits a need for an estimated 21,689 homes in order to accommodate the expected rise in population. Of the current housing units in Leland, approximately 84% are single family homes, 7.2% are mobile homes, and 8.7% are apartments. Overall, residential land area makes up 13,809 acres in Leland's current boundaries. Commercial property makes up 2,695 acres in Leland's current municipal boundaries and 3,628 acres of commercial property currently exist within the 2045 planning area. Community/civic properties make up 863 acres and 4,779 acres of community/civic property exists within the planning area. Finally, 1,168 acres of industrial property exist in the current municipal boundaries and 3,923 acres are found within the 2045 planning area.

4.3.1. Direct Impacts

The built environment within the Town of Leland's boundaries is based on municipal and county zoning codes, depending on whether the development was approved before or after it was within the Town's boundaries. For purposes of the analysis, the Town of Leland's zoning codes can be categorized into four basic categories: Residential, Commercial, Industrial, and Parks or Open Space. Direct impacts to these municipal land parcels from flood hazards can be better understood by identifying the relation of the parcels to the flood zones **Figure 6** displays the land parcel types in relation to flood zones.

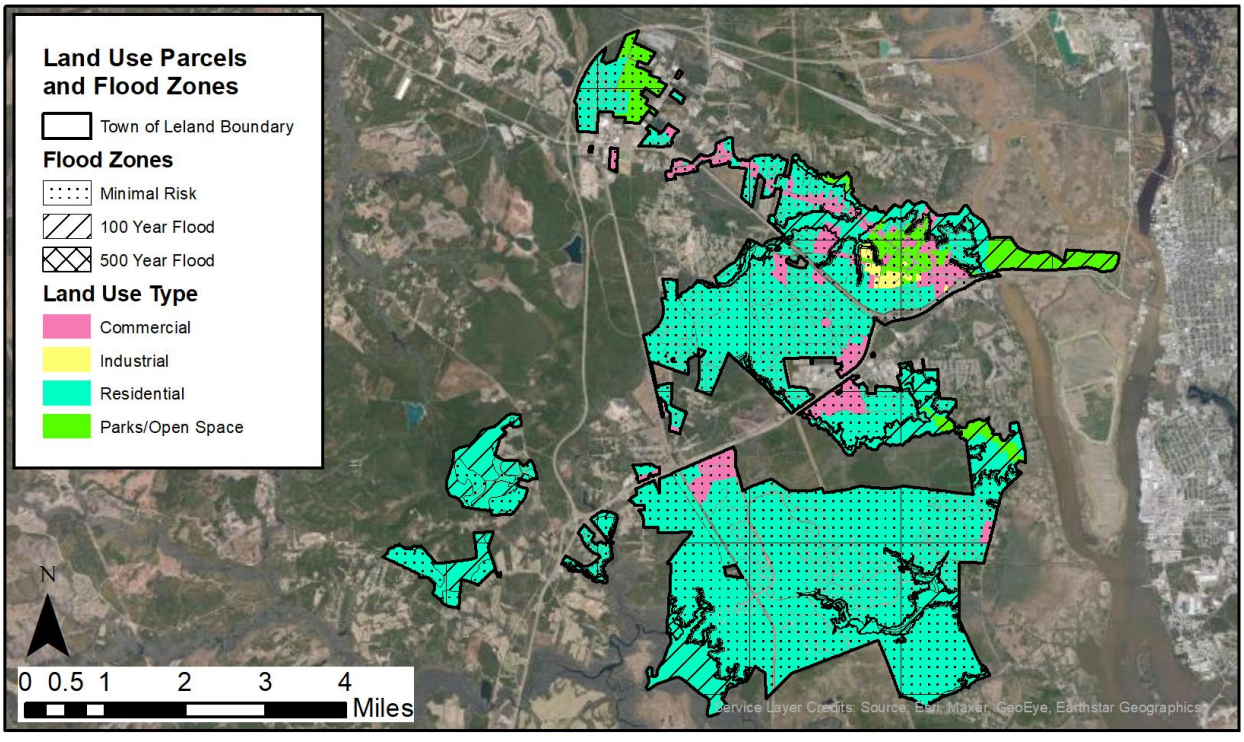

Figure 6. Map displaying the land use patterns according to zoning codes relative to flood zones within the Town of Leland. (Sources: Brunswick County; NC FRIS)

4.3.2. Future Vulnerability and Land Use

A key priority as stated in the Leland 2045 comprehensive land use plan is to "consider development forms that are more resilient to environmental hazards, while accommodating future growth". As previously mentioned, future growth is expected to be significant in the Town, both in population size and in the built environment, in order to accommodate. Understanding where flood risk is highest is crucial in future development planning. For example, a large amount of land area that is designated as Parks/Open Space in **Figure 6** above is found in the 100-year flood zone. This is a key consideration in planning for future growth, especially seeing as residents have put a high value on open space and recreational opportunities, as discussed is section **1.3 Future Land Use Planning**. Additionally, the majority of the residential land areas lie within the Minimal Risk Flood Zone, however those that are in the 100-year flood zone should also be key considerations in future land use changes, policy changes, or other resiliency and hazard mitigation solutions. Other major goals for the Town, as stated in the Leland 2045 comprehensive land use plan, include "transform less-intense uses into a denser, mixed-use pattern in low-risk areas" and to put in place "policies to limit growth or reduce impact of development in 100-year and 500-year floodplains. Understanding where these land use types are found in relation to flood zones is a crucial first step in tackling these goals, as well as others in the future land use planning process.

4.4. Critical Facilities

The Town Hall for the Town of Leland is located at 102 Town Hall Drive. The police department is located within Town Hall and oversees one precinct with 30 officers on staff. The Town of Leland fire department consists of over 40 full-time career staff, part-time positions, and volunteer staff operating out of three fire stations. These staff and volunteers protect and provide service to approximately 35,000 residents in the Town of Leland, the Town of Belville, and parts of northern Brunswick County.

There are four medical facilities located within the Town of Leland's land area: FastMed Urgent Care, AssistedCare Home Health, Wilmington Health Today's Care, and NHRMC Express Care. Leland has two educational facilities within its town boundaries: Leland Middle School and North Brunswick High School. Additionally, there are six day-care facilities in the Town: Kinderstop Kids LLC, Puddle Jumpers, Kids World Academy III, Leland Christian Academy, Childcare Network, and Excel Learning Center. Liberty Healthcare Senior Living is also included in this assessment, as it is in the design phases and is a future critical facility in the Town of Leland.

Emergency evacuation routes were also examined as part of this analysis. The Town of Leland is connected to surrounding municipalities by U.S. Highways and NC Highways. US Highway 74 runs east to west through the Town of Leland and crosses the Cape Fear River into Wilmington via the Isabelle Holmes Bridge. Additionally, US Highway 76 runs east to West through the Town of Leland and crosses the Cape Fear Memorial Bridge. NC Highways 140 and 87 both run North to South through the western portions of the Town and US Highway 17 transects the middle of the Town of Leland boundaries, running North to South as well and connecting Leland to Brunswick County Beaches. See **Figure 7** below for potential emergency evacuation routes.

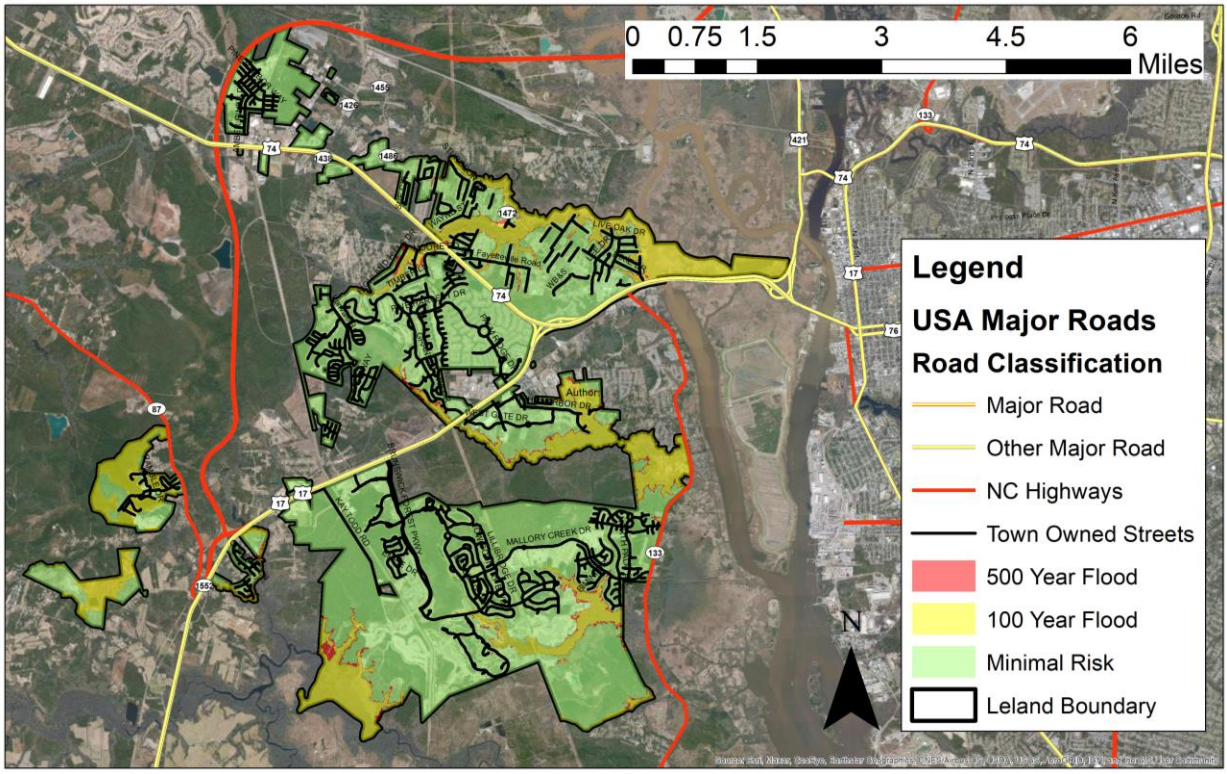

Figure 7. Map displaying streets and major roads and highways as potential emergency evacuation routes for Town of Leland residents. Sources: Brunswick County, ESRI, Tele Atlas North America

4.4.1. Direct Impacts

In the same public survey mentioned in section **4.1.1 Direct Impacts** taken by residents living in and around the Town of Leland, approximately 85% of respondents listed fire stations as being "very important" 72% listed police stations as "very important", and 52% listed schools as being "very important". However, emergency services were ranked as being the second most vulnerable to natural hazards in the eyes of the community members, and infrastructure including schools and day care centers were ranked third. Protecting critical facilities was ranked by approximately 86% of respondents as the first priority from natural hazards, ranking higher than the option of strengthening emergency services. This information is critical in understanding past as well as potential future impacts to these facilities and the public's concern for their safety and wellbeing during times of disasters from natural hazards.

4.4.2. Future Vulnerability and Land Use

One of the Town's major goals moving forward is: "Within growth management planning and zoning, create long term plans to direct new development and critical infrastructure to be less vulnerable from flooding". As part of this goal, the two proposed fire stations will not only account for the steadily increasing population size but are located in areas of minimal risk where they are relatively less vulnerable to natural hazards (see **Figure 8**).

Another goal stated in the Leland 2045 comprehensive land use plan is to incorporate smart growth development principles. These principles include ideas such as more walkable neighborhoods, streets with better connections among destinations, a greater mix of home types,

and more transportation options. According to research in the Town of Leland's 2045 Comprehensive Future Land Use Plan, smart growth development saves an average of 10% on ongoing delivery of services such as police, ambulance, and fire. Smart growth patterns can reduce costs simply by reducing the distances service vehicles must drive. In some cases, the actual number of vehicles and facilities can also be reduced, along with the personnel required. These types of considerations can be crucial in future land use planning to maintain the stability and integrity of critical facilities and their provisions and services.

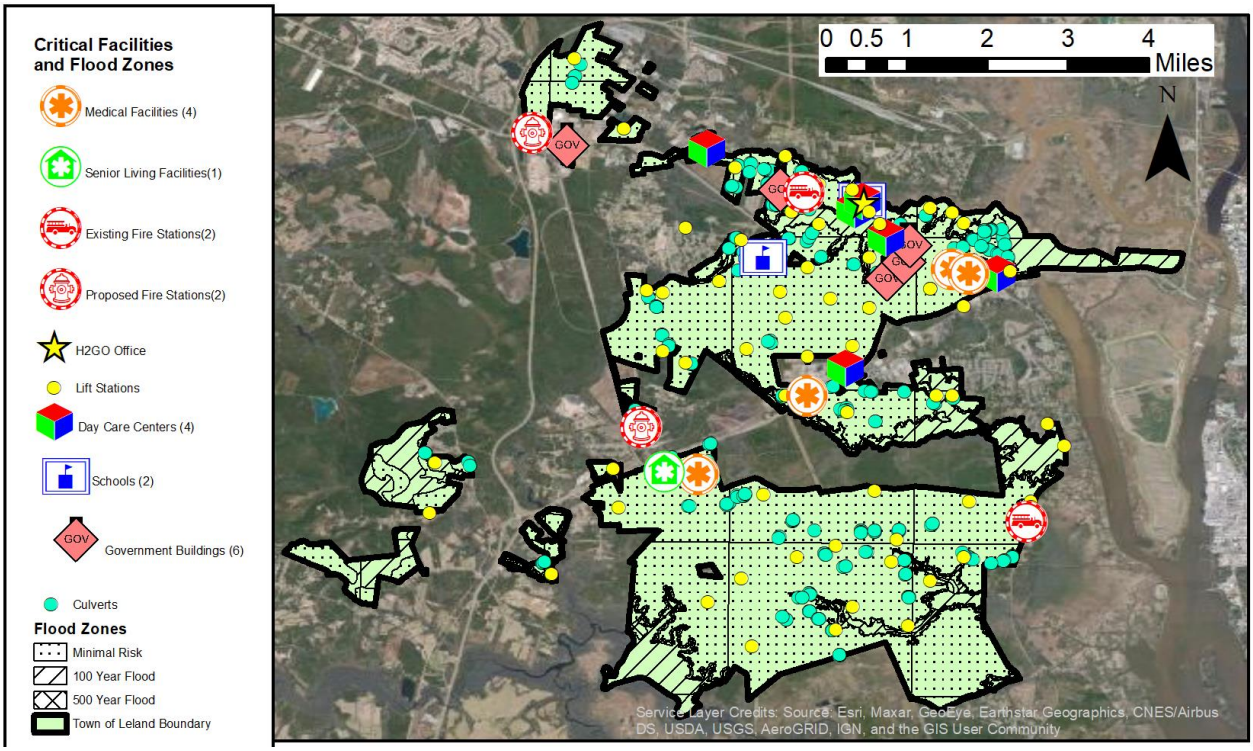

Figure 8. Map displaying critical facilities relative to flood zones within the Town of Leland (Sources: Brunswick County; Town of Leland; NC FRIS)

5. VULNERABILITY ASSESSMENT

This section builds upon the information provided in previous sections by identifying the vulnerable populations and assets. In doing so the Town can better understand the relationship between vulnerable populations, assets, and specific hazards, and can develop specific hazard mitigation plans accordingly.

5.1. Social Vulnerability

To construct the CSC SVI for census blocks within the Town of Leland, American Community Survey (ACS), 2014-2018 (5-year) data at census tract and census block level were used. Where block level data did not exist census tract data was used in its place. For the 15 census variables, the blocks were ranked and for each social vulnerability theme rankings were developed as defined at **Section 2.1.1 Social Vulnerability Methodology. Figure 9** displays the range of vulnerability in the Town of Leland for the four social vulnerability themes.

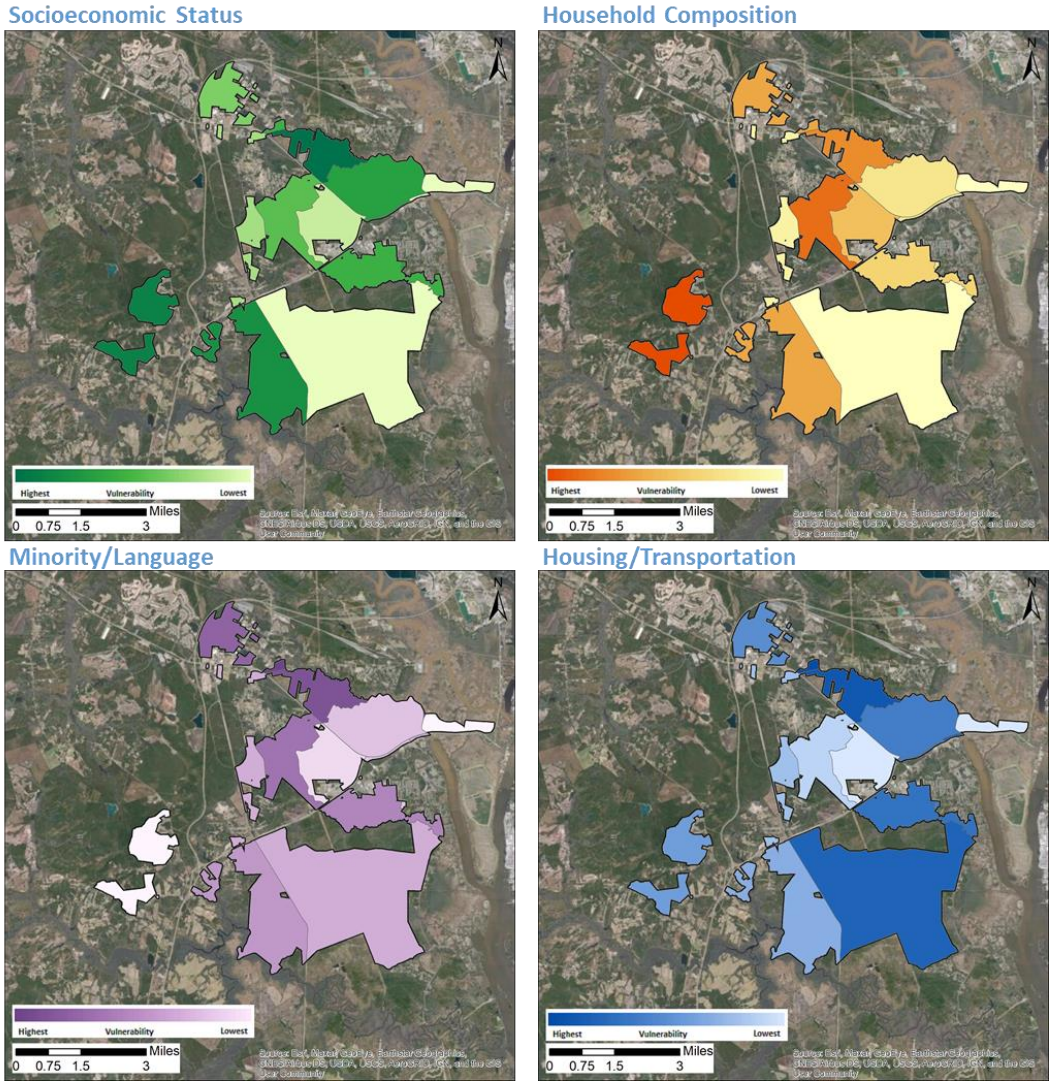

Figure 9. Range of vulnerability in Town of Leland for socioeconomic status theme (lighter colors indicate lower vulnerability and higher colors indicate higher vulnerability)

Additionally, the rankings for the themes were added to develop the overall SVI ranking shown in **Figure 10**. According to the results, the census block at the north of the Town shows the highest vulnerability followed by the growing residential area at the west end of the Town. The north census block also shows highest vulnerabilities among all the social vulnerability themes indicating a need for prioritizing this area in mitigation plans. The west of the Town is also of concern since it displays high to medium vulnerability rankings in themes except minority/language theme.

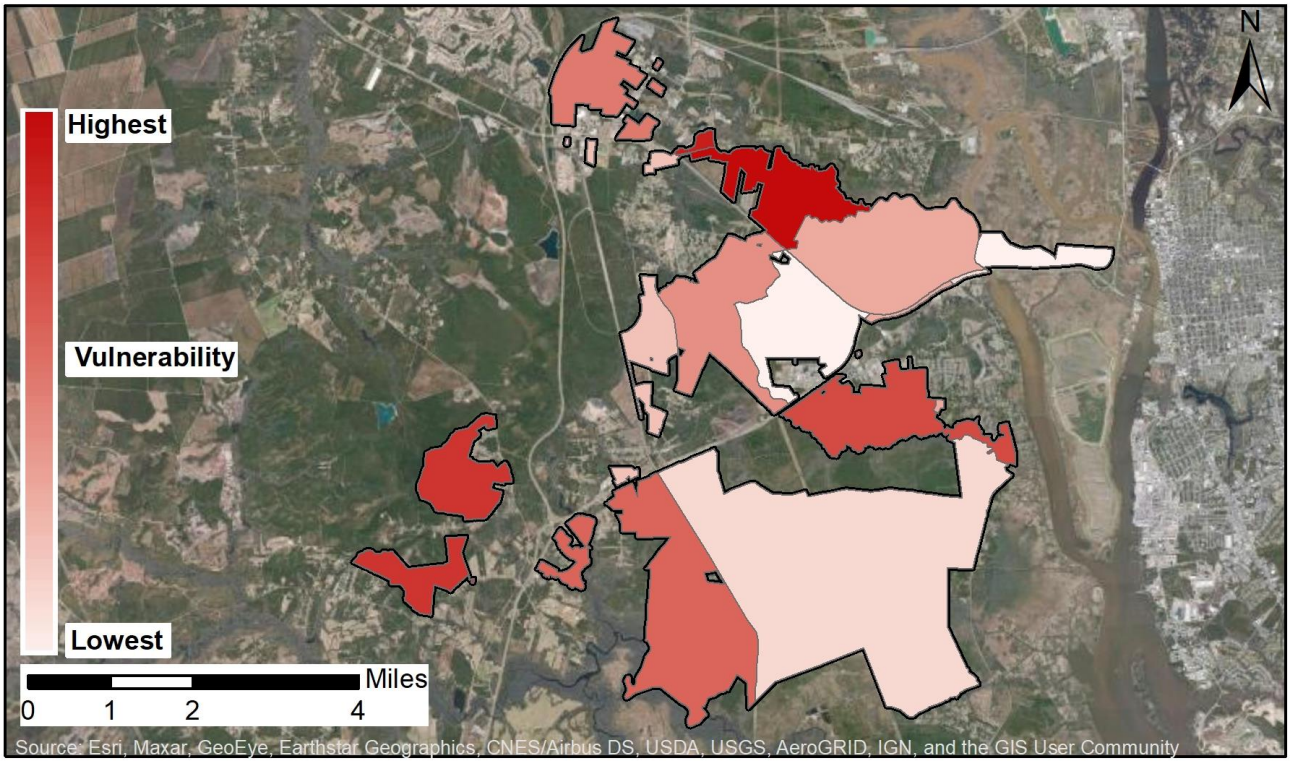

Figure 10. Overall social vulnerability in Town of Leland

5.2. Loss Estimates

The objective of loss estimation calculations is to determine the potential loss to the assets using the best available geospatial data. To generate the GIS building database, the Hazus-MH database was used which includes buildings' first floor elevations, estimated dollar values, and building characteristics such as foundation type, stories, and occupation type. Where building data was not available in the Hazus-MH database, buildings were digitized, and the Brunswick tax records were used to generate the building properties.

For each specific hazard identified in **Section 3 - Hazard Identification,** the geographic boundaries of exposure zones were created as GIS layers. Using these data layers, structure hazard vulnerability can be quantified by estimating the number of buildings exposed to the specific hazard and dollar value of potential damage.

Loss estimates provided in this vulnerability assessment are based on best available data. Due to uncertainties inherent in hazard research, assumptions and simplifications adopted, and

approximations carried out to handle the gaps and inconsistencies in the data, the results should be taken as an approximation of risk and the possible losses.

5.2.1. Flooding

In order to assess possible flood damage, spatial building database was overlaid onto Digital Flood Insurance Rate Map (DFIRM) data. The potential damage to each property within an identified floodplain was then calculated using the USACE Depth-Damage Functions. **Table 5** shows the results of this analysis.

Table 5. Estimated exposure of structures to flooding

	~Number of Exposed Buildings	~Number of Damaged Buildings	Damage
DFIRM 100-year flood	171	144	$14,168,500
DFIRM 500-year flood	264	235	$26,851,900

Figure 11 shows the potential flooding areas which are exposed to the 100-year and 500-year return periods overlaid onto the overall social vulnerability. As can be seen in the figure, the highly socially vulnerable area in the north part of the Town, socially vulnerable areas to the west of the Town and Westgate/133 area are exposed to flooding. In order to decrease the risk from flooding, mitigation projects in these areas should be prioritized.

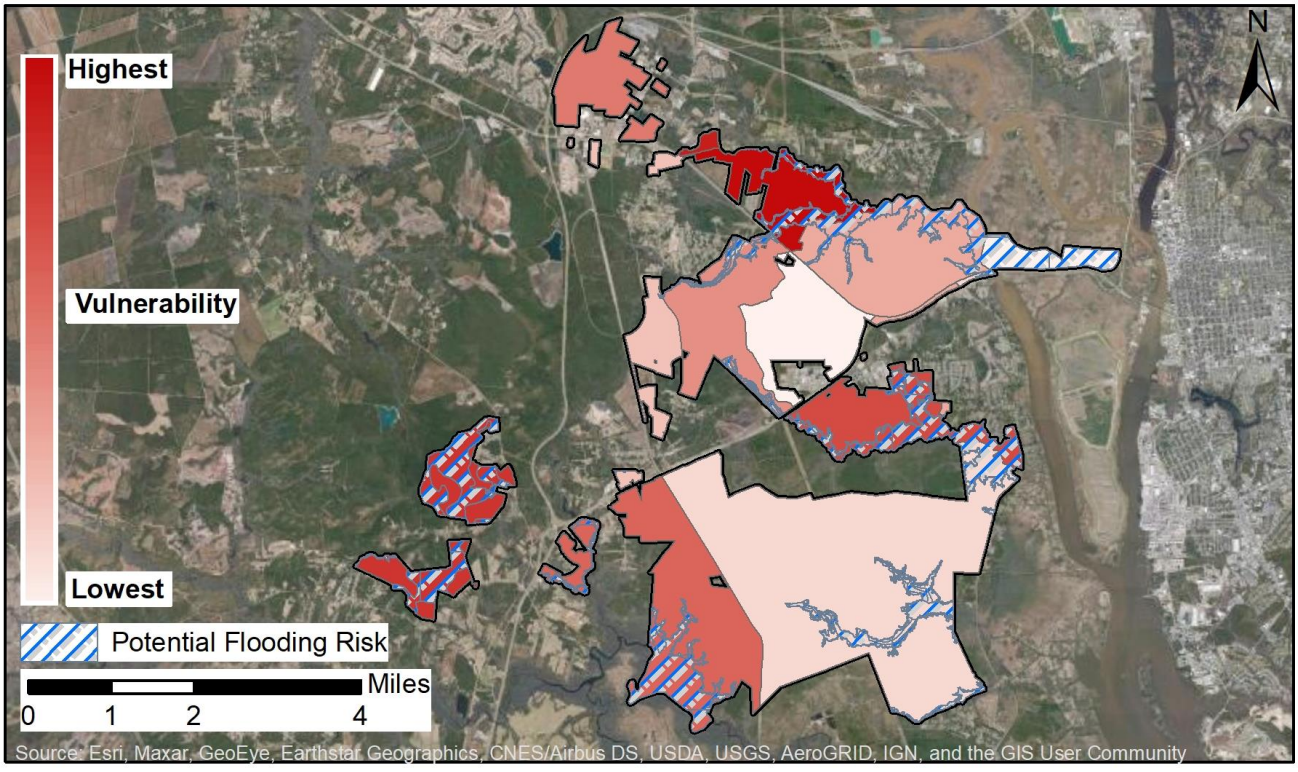

Figure 11. Overall social vulnerability and flooding risk

5.2.2. Storm Surge

For the storm surge vulnerability assessment, the spatial building database was overlaid onto NOAA SLOSH data as described in Section 3.2. The possible damage to each property for each hurricane category modelled by NOAA SLOSH study (Zachry et al., 2015) was then calculated using the USACE Depth-Damage Functions. **Table 6** shows the results of this analysis.

Table 6. Estimated exposure of structures to storm surge

Hurricane Category	~Number of Exposed Buildings	~Number of Damaged Buildings	Damage
1	14	0	-
2	78	10	$1,068,585
3	211	53	$4,179,480
4	565	235	$38,814,465
5	1865	802	$56,929,290

Figure 12 shows the areas exposed to storm surge from a Category 5 storm according to NOAA SLOSH results. As can be seen in the figure, the socially high vulnerable area in the north part of the Town and vulnerable areas to the south and east (Westgate/133) of the Town are exposed to flooding. In order to decrease the risk from storm surge, mitigation projects in these areas should be prioritized.

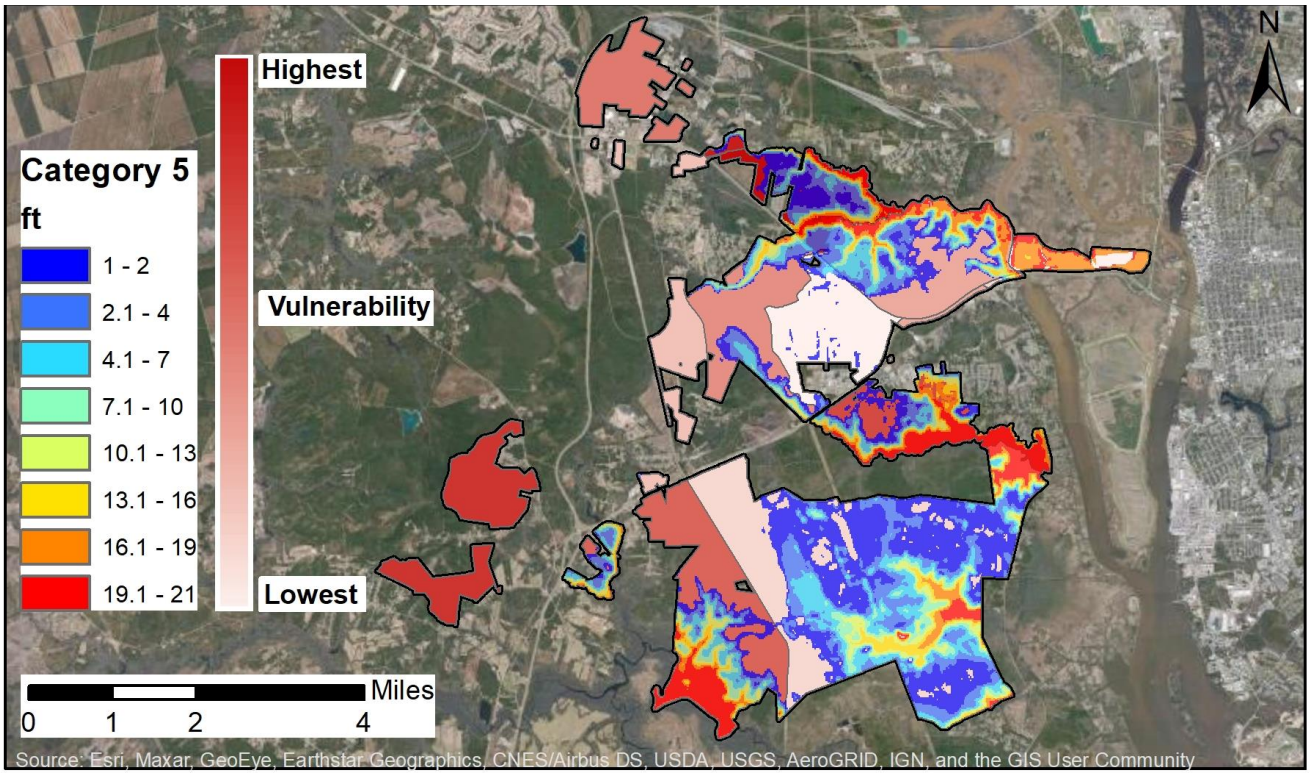

Figure 12. Overall social vulnerability and storm surge risk

5.2.3. Sea Level Rise

In 2017, NOAA integrated the global sea level rise projections developed by the U.S. Interagency Sea Level Rise Taskforce with regional factors contributing to sea level change (Sweet et al., 2017). Based on the 2017 NOAA regional scenarios for Wilmington, NC, the regional sea level is very likely to rise at least 0.7 ft above 2020 levels by 2070 on a low-emissions pathway whereas an intermediate emissions scenario can lead to an increase of 2.9 ft. On future pathways with the highest greenhouse gas emissions, sea level rise could reach approximately 4.9 ft above 2020 levels by 2070.

In order to understand the damage due to possible sea level rise, the inundation maps developed by NOAA, as defined in **Section 3.3 - Sea Level Rise,** were used to identify the structures under risk. Since sea level rise is a long-term event, the total value of the exposed structures was calculated. **Table 7** shows the results of this analysis.

Table 7. Estimated exposure of structures to sea level rise

Sea Level Rise	Appr. Number of Buildings	Total Value of Exposed Structures
1 ft (2070 low-emission)	8	$1,255,950
3 ft (2070 low-emission)	26	$3,613,850
5 ft (2070 low-emission)	62	$5,977,700

5.2.4. Hazard Exposure at Critical Facilities

In order to better understand the vulnerability, critical facilities exposure to hazards analyzed in this section is presented at **Table 8**. The table lists those assets that are determined to be exposed to each of the identified hazards (marked with an “X”). As can be seen from the table none of the critical facilities are located in flooding, storm surge up to a Category 4 hurricane and sea level rise hazard zones. There are seven facilities within a Category 5 hurricane storm surge zone.

Table 8. Exposure of critical facilities to identified hazards (- denotes no exposure and X denotes potential damage from specified hazard)

		Flooding		Storm Surge					Sea Level Rise			Value
		100 year	500 year	Cat. 1	Cat. 2	Cat. 3	Cat. 4	Cat. 5	1 ft	3 ft	5 ft	
Medical Facilities	FastMed Urgent Care	-	-	-	-	-	-	-	-	-	-	$9,862,250
	AssistedCare Home Health	-	-	-	-	-	-	-	-	-	-	
	Wilmington Health Today's Care	-	-	-	-	-	-	-	-	-	-	
	NHRMC Express Care	-	-	-	-	-	-	-	-	-	-	
Fire Stations	Village Road	-	-	-	-	-	-	-	-	-	-	$1,320,720
	Westport	-	-	-	-	-	-	X	-	-	-	
	Station 51	-	-	-	-	-	-	-	-	-	-	NA
	Station 53	-	-	-	-	-	-	-	-	-	-	
Institutions	Leland Middle School	-	-	-	-	-	-	-	-	-	-	$62,115,150
	North Brunswick High School	-	-	-	-	-	-	-	-	-	-	
	Kinderstop Kids LLC	-	-	-	-	-	-	-	-	-	-	
	Puddle Jumpers Forest	-	-	-	-	-	-	X	-	-	-	
	Christian Academy	-	-	-	-	-	-	-	-	-	-	
	Childcare Network	-	-	-	-	-	-	X	-	-	-	
	Excel Learning Center	-	-	-	-	-	-	X	-	-	-	
	Kids World Academy	-	-	-	-	-	-	-	-	-	-	
	Liberty Healthcare Senior Living	-	-	-	-	-	-	-	-	-	-	
Government Buildings	Leland Town Hall	-	-	-	-	-	-	-	-	-	-	$11,109,770
	Brunswick Center at Leland	-	-	-	-	-	-	-	-	-	-	
	Leland Public Library	-	-	-	-	-	-	X	-	-	-	
	Municipal Operations Center	-	-	-	-	-	-	-	-	-	-	
	H2GO Office	-	-	-	-	-	-	X	-	-	-	
	United States Postal Office	-	-	-	-	-	-	-	-	-	-	
	NC State Government Adult Probation and Parole	-	-	-	-	-	-	X	-	-	-	

Table 9. Exposure of lift stations to identified hazards (- denotes no exposure and X denotes potential damage from specified hazard)

Address	Flooding		Storm Surge					Sea Level Rise		
	100 year	500 year	Cat. 1	Cat. 2	Cat. 3	Cat. 4	Cat. 5	1 ft	3 ft	5 ft
8026 Rachel Wynd	-	-	-	-	-	-	-	-	-	-
2325 Hickory Bottom Court	-	-	-	-	-	-	-	-	-	-
727 Avington Lane	-	-	-	-	-	-	-	-	-	-
8110 Compass Pointe E. Wynd	-	-	-	-	-	-	-	-	-	-
1020 Mill Creek Loop	-	-	-	-	-	X	X	-	-	-
1130 Hidden Creek Lane	-	-	-	-	-	-	-	-	-	-
110 Stoney Creek Lane	-	X	-	-	X	X	X	-	-	-
1058 Lanterns Lane	-	-	-	-	-	-	-	-	-	-
46 Waterford Business Center Way	-	-	-	-	-	-	-	-	-	-
2032 Woodwind Drive	-	-	-	-	-	-	-	-	-	-
1137 Spring Glen Court	-	-	-	-	-	-	-	-	-	-
1230 West Gate Drive	-	-	-	-	-	-	X	-	-	-
9960 Chappel Loop	-	-	-	-	-	-	X	-	-	-
9528 Night Harbor Drive	-	-	-	-	X	X	X	-	-	-
10150 Blackwell Road	-	-	-	-	-	-	-	-	-	-
200 Mallory Creek Drive	-	-	-	-	-	X	X	-	-	-
1761 Atkinson Trail	-	-	-	-	-	-	X	-	-	-
9911 Chappell Loop Road	-	-	-	-	-	X	X	-	-	-
148 Buckeye Road	-	-	-	-	-	-	-	-	-	-
2650 Longleaf Pines Circle	-	-	-	-	-	-	-	-	-	-
11 Collins Way	-	-	-	-	-	-	-	-	-	-
2660 Compass South Wynd	-	-	-	-	-	-	-	-	-	-
681 Seathwaite	-	-	-	-	-	-	-	-	-	-
1211 Village Road	-	-	-	-	-	X	X	-	-	-
470 Esthwaite	-	-	-	-	-	-	-	-	-	-
404 Hawthorne	-	-	-	-	-	-	X	-	-	-
8586 Fennel Creek Drive	-	-	-	-	-	-	-	-	-	-
205 Lanvale Road	-	-	-	-	-	-	X	-	-	-
144 Kingsbridge Road	-	-	-	-	-	-	-	-	-	-
1001 Lanvale Road	-	-	-	-	-	-	-	-	-	-

Address	Flooding		Storm Surge					Sea Level Rise		
	100 year	500 year	Cat. 1	Cat. 2	Cat. 3	Cat. 4	Cat. 5	1 ft	3 ft	5 ft
1197 Lanvale Road	-	-	-	-	-	-	-	-	-	-
1027 Lake Norman Lane	-	-	-	-	-	-	-	-	-	-
9698 Eastbrooke Drive	-	-	-	-	-	-	-	-	-	-
1650 Lincoln School Road	-	-	-	-	-	-	-	-	-	-
9751 Old Mill Road	-	-	-	-	-	-	X	-	-	-
9660 Holy Hills	-	-	-	-	X	X	X	-	-	-
9399 Sue Circle	-	-	-	-	-	-	-	-	-	-
9851 Sturgeon Drive	-	-	-	X	X	X	X	-	-	-
9789 Wayne Street	-	X	-	-	-	X	X	-	-	-
840 Appleton Way	X	X	X	X	X	X	X	-	X	X
756 Village Road	X	X	-	-	X	X	X	-	X	X
1874 Brunswick Village Boulevard	-	-	-	-	-	-	-	-	-	-
628 Pine Branches Circle	-	-	-	-	-	X	X	-	-	-
821 Beachwalk Drive	-	-	-	-	-	-	X	-	-	-
120 Eric Court	-	X	-	-	X	X	X	-	-	-
1478 River Road	-	-	-	-	-	-	X	-	-	-
Egret Nest Circle	-	-	-	-	-	-	X	-	-	-
10164 Creekside Drive	-	-	X	X	X	X	X	-	-	-
1035 River Road	X	X	-	X	X	X	X	-	-	X
10205 Mariners Cove	-	-	-	-	X	X	X	-	-	-
959 Jackeys Creek Lane	X	X	-	X	X	X	X	-	-	X
9822 Olde Towne Wynd	X	X	-	X	X	X	X	-	-	-
10205 Olde Towne Wynd	-	-	-	-	-	-	X	-	-	-
434 River Road	-	-	-	X	X	X	X	-	-	-
590 River Road	-	-	-	-	-	-	-	-	-	-
238 Main Street	-	-	-	X	X	X	X	-	-	-
9400 Holbrook Drive	-	-	-	-	-	-	X	-	-	-
985 Old Fayetteville Road	X	X	-	-	X	X	X	-	-	-
119 Lake Drive	X	X	-	X	X	X	X	-	X	X
139 S. Navassa Road	-	-	-	-	-	-	X	-	-	-
100 Live Oak	-	X	-	X	X	X	X	-	-	-
86 Baldwin Drive	-	-	-	-	-	-	X	-	-	-

Address	Flooding		Storm Surge					Sea Level Rise		
	100 year	500 year	Cat. 1	Cat. 2	Cat. 3	Cat. 4	Cat. 5	1 ft	3 ft	5 ft
1501 Olde Waterford Way	-	-	-	-	-	-	-	-	-	-
164 Old Fayetteville Road	-	-	-	-	-	-	X	-	-	-
125 Rampart Drive	X	X	-	X	X	X	X	-	-	-
2000 Royal Palm Way	-	-	-	-	-	-	-	-	-	-
117-K Village Road	-	-	-	-	-	-	-	-	-	-
1231 Greensview Circle	-	-	-	-	-	-	-	-	-	-
8691 Orchard Loop Road	-	-	-	-	-	-	-	-	-	-
1165 Willow Pond Lane	-	-	-	-	-	-	-	-	-	-
8900 Timber Lane	-	-	-	-	-	-	-	-	-	-
1005 Cornerstone Drive	-	-	-	-	-	-	-	-	-	-
1035 Grandiflora Drive	-	-	-	-	-	-	X	-	-	-
2797 Southern Magnolia Drive	-	-	-	-	-	-	X	-	-	-
996 Kay Todd Road	-	-	-	-	-	-	-	-	-	-
7120 Pungo Lake Court	-	-	-	-	X	X	X	-	-	-
2119 Southern Pine Drive	-	-	-	-	-	-	-	-	-	-
3060 Broadhaven Drive	-	-	-	-	-	-	-	-	-	-
3101 Smeads Drive	-	X	-	X	X	X	X	-	-	
2401 Shelmore Way	-	-	-	-	-	X	X	-	-	-
1211 Cape Fear National Drive	-	-	-	-	X	X	X	-	-	-
1238 Sleepy Oak Lane	-	-	-	-	-	-	X	-	-	-
2092 Wind Lake Way	-	-	-	-	-	-	-	-	-	-
1010 Stony Woods Lane	-	-	-	-	-	-	-	-	-	-
5000 Rice Gate Way	-	-	-	-	-	-	X	-	-	-
2015 Annsdale Drive	-	-	-	-	-	-	X	-	-	-
1700 Low Country Boulevard	-	-	-	-	-	-	X	-	-	-
2035 Pine Harvest Drive	-	-	-	-	-	-	-	-	-	-
151 Forest Hills Drive	X	X	-	X	X	X	X	-	X	X

5.2.5. Vulnerability Score of Critical Facilities

Vulnerability of critical assets to a hazard (flooding, storm surge and sea level rise) can be conceptualized as a combination of three vulnerability components: exposure, sensitivity and adaptive capacity. In this report exposure refers to the probability of physical contact between an asset and a hazard. Sensitivity is the degree to which an assets function is impacted by a hazard.

Adaptive capacity is the ability of an asset to change its characteristics or behaviors in response to a hazard. These definitions are then aggregated to generate an overall vulnerability ‘‘score’’ for each critical asset using the following formula:

$$\text{Vulnerability} = \text{Exposure} + \text{Sensitivity} - \text{Adaptive Capacity}$$

A survey was distributed to the CAT of the Town (from December 14th, 2021 to December 20th, 2021) to elicit the exposure, sensitivity and adaptive capacity scores for each critical asset. Then the exposure, sensitivity and adaptive capacity scores were aggregated to generate an overall vulnerability score for each critical asset. According to the results that can be seen in **Table 10**, governmental buildings in the Town have higher vulnerability score thus should be given priority.

Table 10. Vulnerability score of critical facilities to identified hazards

		Exposure	Sensitivity	Adaptive Capacity	Vulnerability Score
Medical Facilities	FastMed Urgent Care	0	1	2	-1
	AssistedCare Home Health	0	1	2	-1
	Wilmington Health Today’s Care	0	1	2	-1
	NHRMC Express Care	0	1	2	-1
Fire Stations	Village Road	0	3	2	1
	Westport	1	3	2	2
	Station 51	0	3	2	1
	Station 53	0	3	2	1
Institutions	Leland Middle School	0	2	1	1
	North Brunswick High School	0	2	1	1
	Kinderstop Kids LLC	0	1	1	0
	Puddle Jumpers Forest	1	1	1	1
	Christian Academy	0	1	1	0
	Childcare Network	1	1	1	1
	Excel Learning Center	1	1	1	1
	Kids World Academy	0	1	1	0
	Liberty Healthcare Senior Living	0	2	2	0
Government Buildings	Leland Town Hall	0	3	2	1
	Brunswick Center at Leland	0	3	1	2
	Leland Public Library	1	1	2	0
	Municipal Operations Center	0	3	2	1
	H2GO Office	1	3	2	2
	United States Postal Office	0	3	1	2
	NC State Government Adult Probation and Parole	1	2	1	2

6. REFERENCES

Brunswick County Economic Development and Planning, 2017. Brunswick County Data Book. Available online: https://www.brunswickcountync.gov/files/planning/2015/04/Brunswick-County-Data-Book-1.pdf

Carter, A.B., 2016. The History and Timeline of Leland, NC. https://lifeinbrunswickcounty.com/the-history-and-timeline-of-leland-nc/

Centers for Disease Control and Prevention (CDC). (2015) Planning for an Emergency: Strategies for Identifying and Engaging At-Risk Groups: A guidance document for Emergency Managers: First edition. Atlanta (GA): CDC; 2015.

County Office, 2021. Leland Police Department in Leland, North Carolina. Available online: https://www.countyoffice.org/leland-police-department-leland-nc-1cd/

Federal Emergency Management Agency. Disaster Declarations for States and Counties. Available online: https://www.fema.gov/data-visualization/disaster-declarations-states-and-counties

Flanagan, B., Gregory, E., Hallisey, E., Heitgerd, J. & Lewis, B. (2011). A Social Vulnerability Index for Disaster Management. *Journal of Homeland Security and Emergency Management*, *8*(1), 000010222021547735517 92. https://doi.org/10.2202/1547-7355.1792

Moffatt & Nichol, 2021.Leland RCCP Survey Analysis.

N.C. Coastal Resources Commission Science Panel, *North Carolina Sea Level Rise Assessment Report, 2015 Update to the 2010 Report and 2012 Addendum.* North Carolina Department of Environmental Quality, Division of Coastal Management. https://deq.nc.gov/media/5975/download. March 31, 2015.

Sweet, W.V., R.E. Kopp, C.P. Weaver, J. Obeysekera, R.M. Horton, E.R. Thieler, and C. Zervas, 2017: Global and Regional Sea Level Rise Scenarios for the United States. NOAA Technical Report NOS CO-OPS 083. NOAA/NOS Center for Operational Oceanographic Products and Services.

Town of Leland, 2021. Town of Leland Comprehensive Land Use Plan 90% Draft Document. Town of Leland staff and consultants. Available online: https://www.townofleland.com/sites/default/files/uploads/documents/leland2045_draft_90perc_210928.pdf

Town of Leland. 2021. Fire/Rescue Town of Leland. Available online: https://www.townofleland.com/firerescue

U.S. Army Corps of Engineers. Physical Depth Damage Function Summary Report, North Atlantic Comprehensive Coastal Study: Resilient Adaptation to Increasing Risk. Available online: https://www.nad.usace.army.mil/Portals/40/docs/NACCS/10A_PhysicalDepthDmgFxSummary_26Jan2015.pdf (accessed on 10 November 2021).

U.S. Census Bureau, 2019. American Community Survey 5-year estimates. Retrieved from Census Reporter Profile page for Leland, NC. Available Online: http://censusreporter.org/profiles/16000US3737680-leland-nc/

Zachry, B. C., W. J. Booth, J. R. Rhome, and T. M. Sharon, 2015: A National View of Storm Surge Risk and Inundation. Weather, Climate, and Society, 7(2), 109–117. DOI: http://dx.doi.org/10.1175/WCAS–D–14–00049.1